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Influence Analysis of Shielding Gas Flow Rate and Purity Level Variation on GMAW Welding Process to Microstructure of Alumunium 5083

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ABSTRACT
Aluminium is a commonly used material in construction and transportation industries. The advantages of using the aluminium material are its light weight, corrosion resistant, and the capability to form an alloy with another metal. Therefore, the aim of this research is to analyze the influence of shielding gas flow rate and purity level variation to mechanical properties and microstructure of the welded material. The welding process used on this research was the GMAW method. The material used was aluminium 5083 series with 300 mm x 150 mm x 8 mm dimensions. The shielding gases used were high purity (HP) and ultra-high purity (UHP) argon (Ar). The variations of shielding gas flow rate used were 16, 18, dan 20 litre/minutes. Based on the tensile test that has been done, the variation of UHP argon gas with 20 litre/minute flow rate had the best result with yield strength of 217,32 MPa and ultimate strength of 295,83 MPa. The result of the micro photos showed that the GMAW method produced small dots where the dots were Mg2Si formation, which the greater number of smaller size dot produced would increase the mechanical properties of the material.

Keywords: *GMAW, aluminium 5083 series, mechanical properties, microstructure.*

1. INTRODUCTION

Today's technology advances very rapidly, especially in construction development. Welding technology is very necessary on construction development process, especially in maritime industries. Infrastructure and various kind of ship constructions can't be separated from some kind of failure [1]. Offshore structures, pipes, and various platforms gradually suffer damage due to environmental factors[2]. Because of that, the strength of welded joint is very important while regular maintenance and testing must be done to know the endurance of a platform to the load received[3]. Therefore, skills in welding practice are needed to ensure the safety of the welding application in the platform joint.

In ship construction, one of the materials that can be used is the 5083 series aluminium. Aluminium is one of the best material on the industries due to its lightweight and strong properties. In addition, aluminium also has excellent corrosion resistance making it suitable to use in construction in the maritime industries. But one of the disadvantages of aluminum is relatively more expensive than steel. Aluminum 5083 can replace fiber as one of the materials used in the manufacture of fast boats, because fiber has properties that cannot be recycled so that it can cause problems to the environment [4]. By using aluminium series 5083, it is hoped that it can reduce environmental problems.

In practice, it is common to use gas metal arc welding (GMAW) method on aluminium 5083 series. GMAW is very suitable for aluminium joint because it is using inert gas as the shielding gas. This shielding gas has a function to protect arcs and metal liquids from oxygen and nitrogen gases in the atmosphere of the welding environment. Shielding gases that commonly used in GMAW are argon (Ar), mix of argon and helium (He) or carbon dioxide (CO_2). But in the practice of aluminium welding, the only shielding gas that can be used is pure argon gas.

There are two types of argon gas that commonly used, namely high purity (HP) and ultra-high purity (UHP) argon gas. Flow rate and purity level of the argon gas will affect the result of the welding especially on the mechanical properties and the microstructure of the welded material. To determine the mechanical properties and microstructure from the welded material, it is required to do mechanical test and microstructure photos observation.

2. BASIC THEORY

2.1 Aluminium 5083

Aluminium 5083 alloy is compatible with very low temperature (cyrogenic) of -165˚C (-265 ˚F) because this alloy does not show ductile-brittle phenomenon. This alloy has a Al_2O_3 passive layer that has melting point of 2200 ˚C. This alloy is commonly used for body ship design, underwater tool and vehicle, etc. Therefore, this 5 series aluminium often called as marine used material. Aluminium 5083 is a material that can not change its mechanical strength by heat treatment or also known as non heat treatable material [5].

Aluminum 5083 is known to be very strong after the welding process. This aluminum alloy can withstand extreme conditions. In addition, it also has corrosion resistance to sea water and industrial chemicals. But this type of Aluminum alloy 5083 is not recommended to use at temperatures over 65 ˚C. Aluminium 5083 alloy chemical composition is shown in Table 1.

Table 1. Chemical composition of Aluminium 5083 according to ASM Handbook vol. 6

Composition of Al 5083							
%Si	%Fe	%Cu	%Mn	%Mg	%Cr	%Zn	%Ti
0,40	0,40	0,10	0,40-1,0	4,0-4,9	0,05-0,25	0,25	0,15

2.2 Gas Metal Arc Welding

GMAW is also known as metal inert gas (MIG) welding. GMAW (Gas Metal Arc Welding) is one of the welding method that use heat input to melt down the wire reel as the electrode and also using a shielding gas in the process. This welding process could use alternating current (AC) or direct current (DC), that depends on the metal type used as the welded material. Direct current used for steel, cast iron, copper alloy, and corrosive resistance steel welding. The alternating current usually used for aluminium, cast iron, and some other metals. This process is mostly carried out for welding thin plates, because the cost will be more expensive if used for welding thick plates. This type of welding offers higher efficiency and faster welding speed. This welding is generally carried out automatically. The shielding gases used are argon gas, helium or a mixture of both. To stabilize the arc sometimes it needs an addition of O_2 gas between 2% to 5% or CO_2 between 5% to 20% [6].

Metal welding process required by the manufacturing industry is by liquid welding, such as using gas metal arc welding (GMAW). Gas metal arc welding is a method of welding where the gas is blown into the welding area to protect arcs and metals that melt against the atmosphere [7].

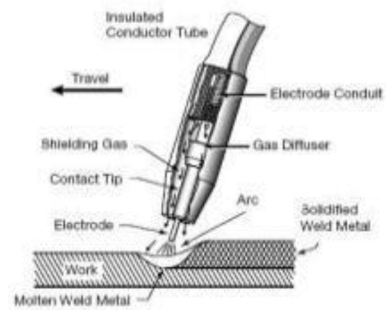

Figure 1. Gas Metal Arc Welding Method

2.3 Shielding Gas

Shielding Gas is a gas that serves to protect the welding metal liquid (filler metal and main metal) from the surrounding environment air to prevent the oxidation process between the welding metal with the outside air. At high temperatures, oxygen reacts with the welding metals to form metal oxides. Oxygen can also reacts with carbon in the liquid metal weld to form CO (carbon monoxide) and CO_2 (carbon dioxide). The reaction process of the liquid welding metal with the surrounding outside air can also produce various kinds of welding defects, therefore the oxygen and nitrogen must be isolated from the liquid welding metal.

The protective gas that is widely used for GMAW welding is argon gas. Argon gas (Ar) is a monatomic inert gas with a molecular weight of 40 which can be obtained by liquefying air. The gas used for welding is pure argon gas (at minimum 99.95%) for metals that are not reactive, but for reactive metals and heat-resistant metals, the level of purity is higher (99.997%). For GMAW the argon gas commonly used are high purity argon gas (HP) with a purity level of 99.95% and ultra-high purity argon gas (UHP) with a purity level of 99.997%.

Argon gas is more often used because it has some advantages compared to other protective gases such as:

- Smoother flame resulting in quieter sound
- Low penetration suitable for thin materials
- Has cleaning properties
- Cheaper and easier to obtain
- Does not need high flow rate
- More resistant to gust of wind
- Easier to light an electric arc

2.4 Microstructure Observation Test (Metallography)

Microstructure testing is observing a material using magnification through a metallographic microscope. This test is carried out to observe the microstructure of a material and damage on the material due to deformation, heat treatment process and differences in composition. To do this metallographic test, there are some step that must be done. The material to be tested must go through a process of mounting, grinding, polishing, and etching. From those stage, the grinding and polishing processes are more important to be done so that the surface of the test specimen become smoother resulting in clearer and more accurate observation of the microstructure. This process is carried out using a special material polishing machine. After doing these stages then the material is ready to be observed. Things that can be observed from this observation are differences in material composition, material damage due to deformation, grain shape and size, differences in microstructure of the material, micro defects, and material impurity.

3. RESULT AND DISCUSSION

3.1 Welding Procedure Specification (WPS)

In this research, welding process was carried out at Welding Centre Laboratory located in PPNS Surabaya. Welding Procedure Specification (WPS) used as a reference for this welding is shown in Table 2.

Table 2. Welding Procedure Specification (WPS)

Welding Process	GMAW
Joint Design	*Butt Joint*
Groove	*Single V- groove*
Base Metal	Aluminium 5083
Filler Metal	ER 5356, diameter 1,2 mm
Position	1G
Shielding Gas	Argon HP & UHP
Flow Rate	16 L/minutes, 18 L/minutes, 20 L/minutes
Volt Range	18 – 26 V
Ampere	150 A

3.2 Microstructure Test

The purpose of microstructure test is to observe the microstructure changes of the material. For this research, the material used was aluminium 5083 weld joint using the gas metal arc welding process.

Before the test began, the specimen was polished to make it easier to be observed. Polishing was done gradually using sandpaper 80, 120, 240, 400, 600, 800, 1000, 1500, and 2000. Not only that, the polishing process was also continued by using alumunia liquid so that the surface of the specimen to be observed would become shinier.

After that, the etching process was carried out, etching is a process of lubricating the test specimen with a chemical solution. The chemical solution used for the aluminum specimen 5083 was a Keller's Reagent solution consisting of HF, HCl, HNO_3, and H_2O compounds. The purpose of this process is to erode the surface of the specimen so that the Base Metal area, HAZ (Heat Affected Zone), and Weld Metal were easier to be observed.

On the observation of aluminium 5083 microstructure, the photo was taken using 500x magnification. The areas observed were Base Metal, HAZ (Heat Affected Zone), and Weld Metal. According to Atlas Microstructure of Aluminum, Alumunium 5083 series consist of Mg_2Al_3 and $(FeMn)_3SiAl_{12}$ compounds.

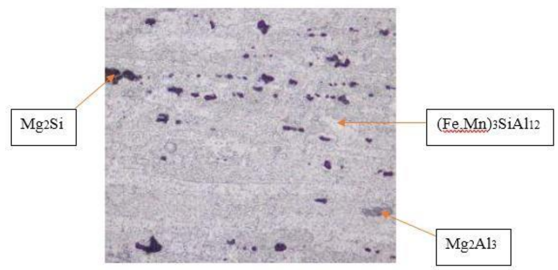

Figure 2. Microstructure of aluminium 5083

Because of the welding process, there are some black particle formed in the specimen, which was β Mg_2Si compounds, there were also α compounds that shown by the bluish particle which was Mg_2Al_3 compounds and the grey particle was $(FeMn)_3SiAl_{12}$ compounds. The welding process certainly required the heat treatment to be done, which could change the microstructure of the specimen, especially in the HAZ (Heat Affected Zone). This area was the one that got the most heat so it released Magnesium (Mg) which eventually formed a compound with Silicon (Si) (Junus, 2011). Therefore, this area also had coarser grains. The presence of Silicon (Si) was due to the filler metal used in welding, namely ER5356 containing the additional Silicon (Si) element so that the Mg_2Si compounds were formed.

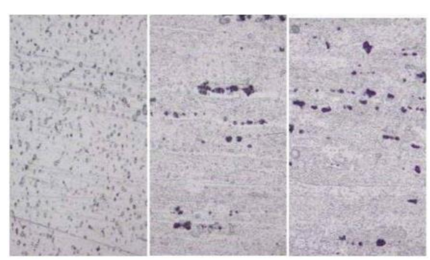

Figure 3. Microstructure of HP16 Specimen

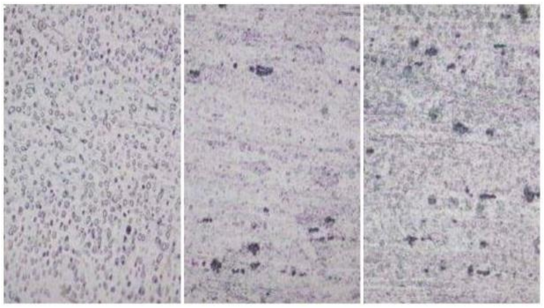

Figure 4. Microstructure of HP18 Specimen

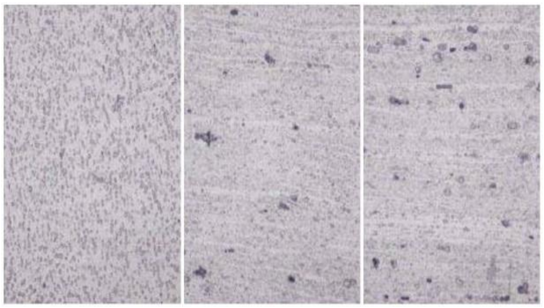

Figure 5. Microstructure of HP20 Specimen

Table 3. Percentage α and β Specimen with Argon HP

Average	Percentage	
	α (Mg_2Al_3 and $(FeMn)_3SiAl_{12}$)	β (Mg_2Si)
BM 16 L/minutes	49%	51%
WM 16 L/minutes	40%	60%
HAZ 16 L/minutes	48%	52%
BM 18 L/minutes	49%	51%
WM 18 L/minutes	41%	59%
HAZ 18 L/minutes	47%	53%
BM 20 L/minutes	49%	51%
WM 20 L/minutes	44%	56%
HAZ 20 L/minutes	44%	56%

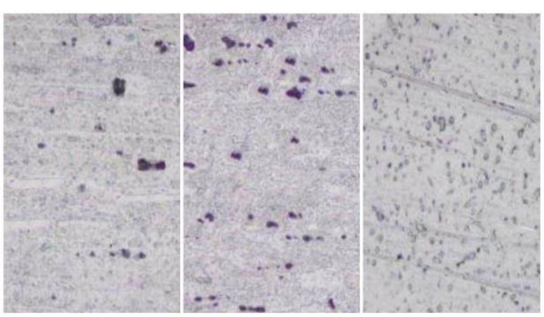

Figure 6. Microstructure of UHP16 Specimen

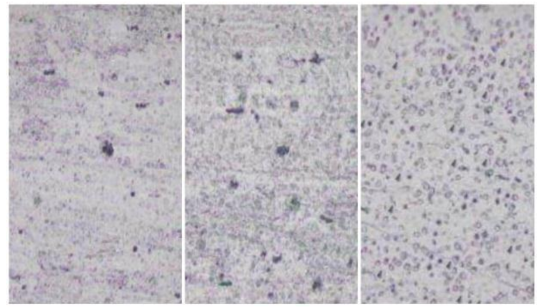

Figure 7. Microstructure of UHP18 Specimen

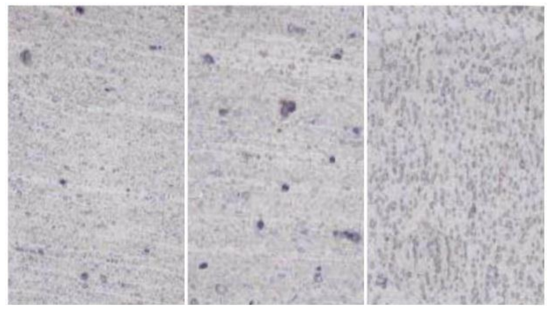

Figure 8. Microstructure of UHP18 Specimen

Table 4. Percentage α and β Specimen with Argon HP

Average	Percentage	
	α (Mg_2Al_3 and $(FeMn)_3SiAl_{12}$)	β (Mg_2Si)
BM 16 L/minutes	48%	52%
WM 16 L/minutes	39%	61%
HAZ 16 L/minutes	46%	54%
BM 18 L/minutes	48%	52%
WM 18 L/minutes	40%	60%
HAZ 18 L/minutes	45%	55%
BM 20 L/minutes	48%	52%
WM 20 L/minutes	43%	57%
HAZ 20 L/minutes	42%	58%

Table 3. and Table 4. shows that there is an increasing quantity of the grains, which is the Mg2Si compound, with the increase of the flow rate used in welding process. By the increase of the Mg2Si (β) percentage, the mechanical properties of the material will increase too. But the size of the grains could be scaled down by using the ultra-high purity (UHP) argon gas so it could make the spread of Mg2Si (β) more evenly. By reducing the size of the Mg2Si (β) grains, it will increase the toughness of the material.

Therefore the material welded using ultra-high purity (UHP) argon gas with a flow rate of 20 L / min had the best toughness and mechanical properties compared to other specimens.

4. CONCLUSION

From the observations of the microstructure test photo results, aluminium 5083 welding with variations of purity level and flow rate of the argon gas produced small grains where the smaller grain size and the larger number of grains could improve the mechanical properties and toughness of the material. By increasing the shielding gas flow rate that was used, it would also increase the formation of Mg2Si compounds. Meanwhile, with the application of purer argon gas, namely ultra-high purity (UHP) argon gas, smaller Mg2Si granules could be produced so that it would increase the mechanical properties of welded materials.

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